Probabilistic Resource Adequacy Methods

Update from Recent EPRI Initiative

ENERGY DELIVERY AND CUSTOMER SOLUTIONS

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ESIG/G-PST Webinar
Feb 26, 2024

Why is Resource Adequacy (RA) such a hot topic now?

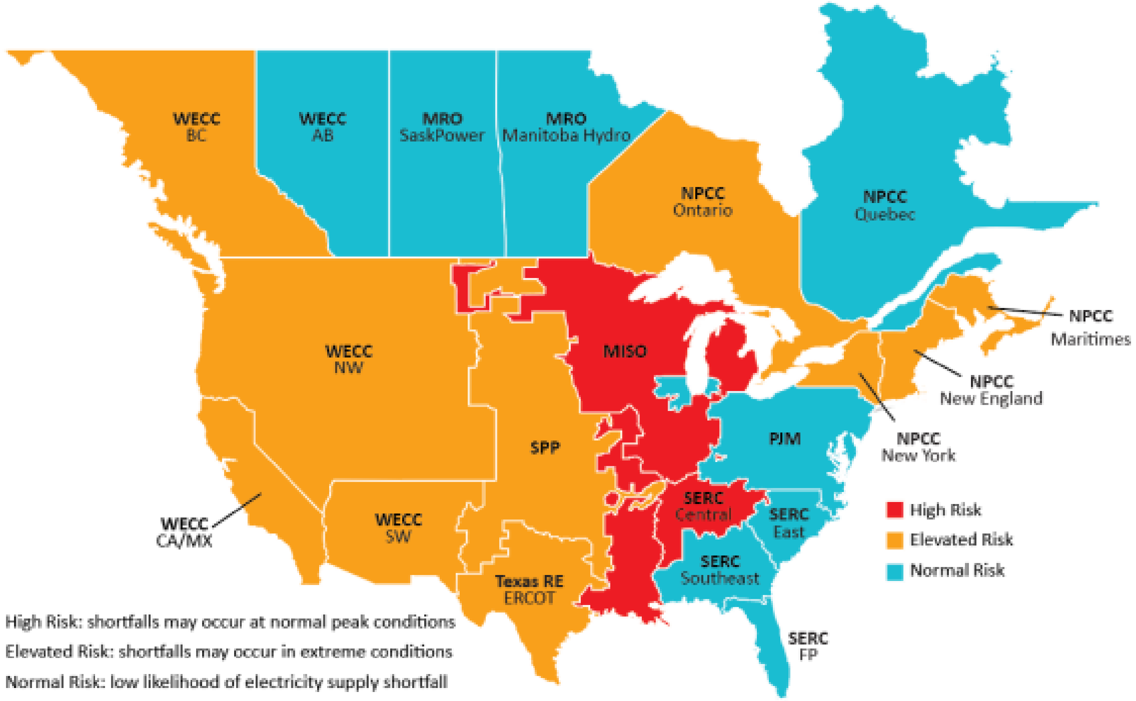
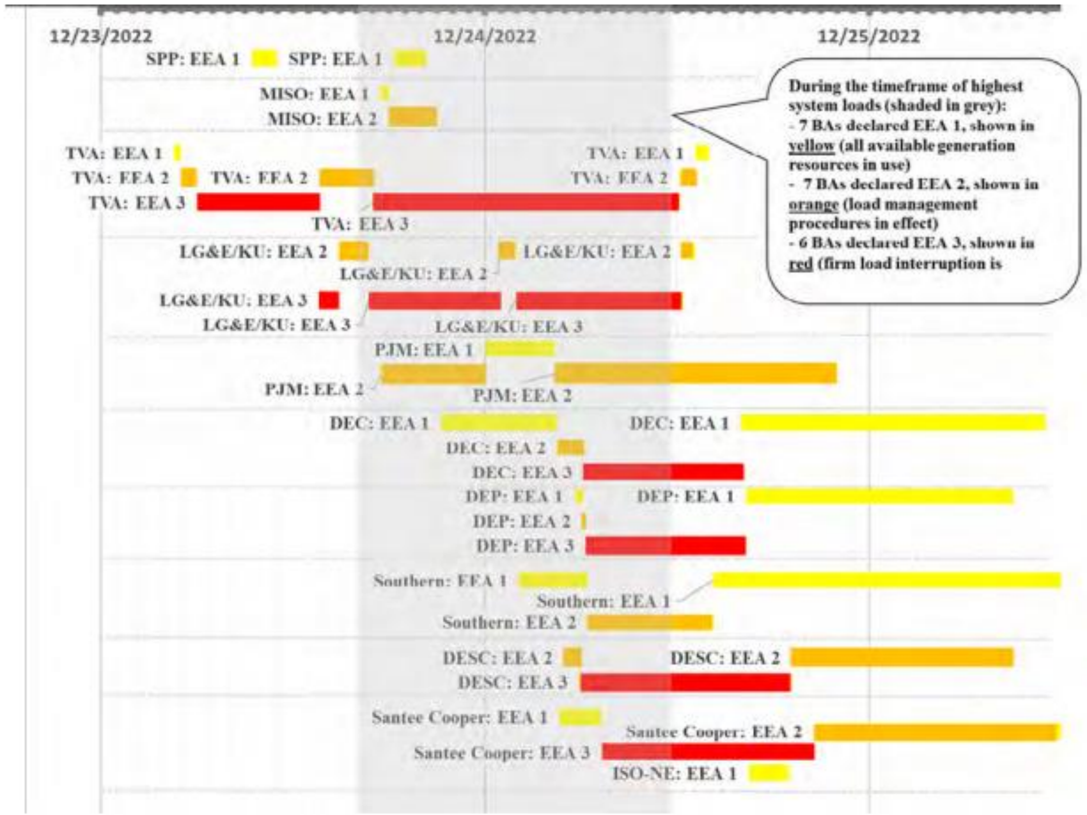


Figure 1: Risk Area Summary 2024–2028[8]



NERC Long Term Reliability Assessment

- Elevated or high risk in many regions
- Winter fuel supply a major challenge
- Capacity reserves a challenges in some regions

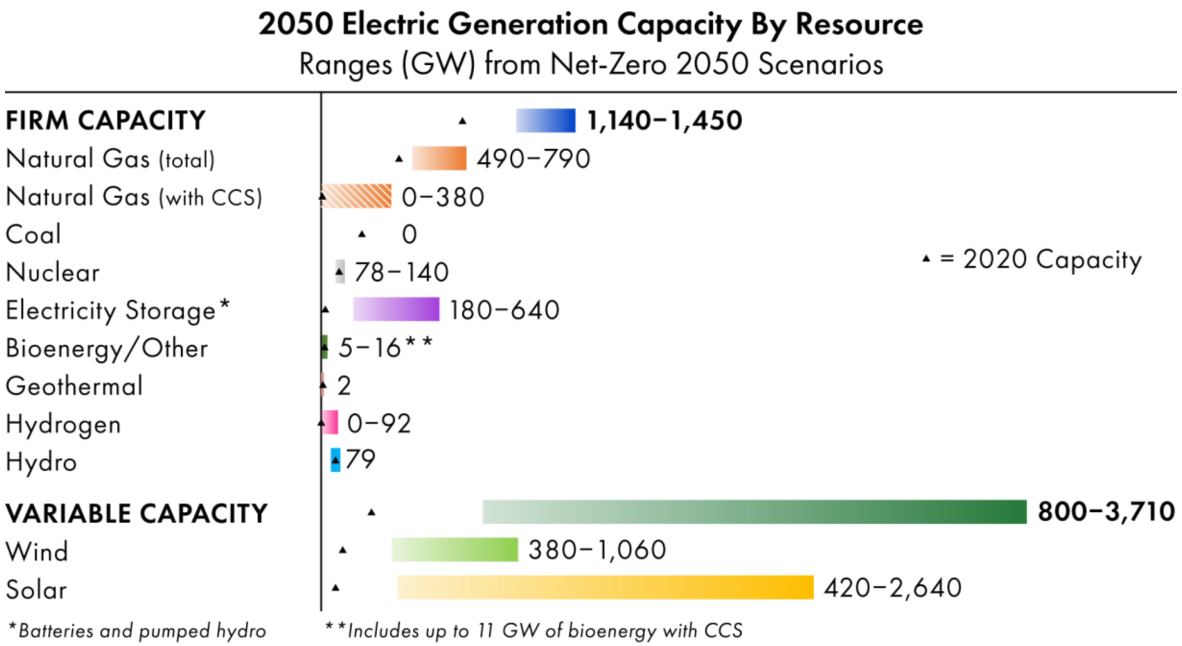
Recent Events

- Winter storm Elliott (end 2022)
- Winter storm Uri (early 2021)
- Alberta (early 2024)

Source: NERC Long Term Reliability Assessment (link)

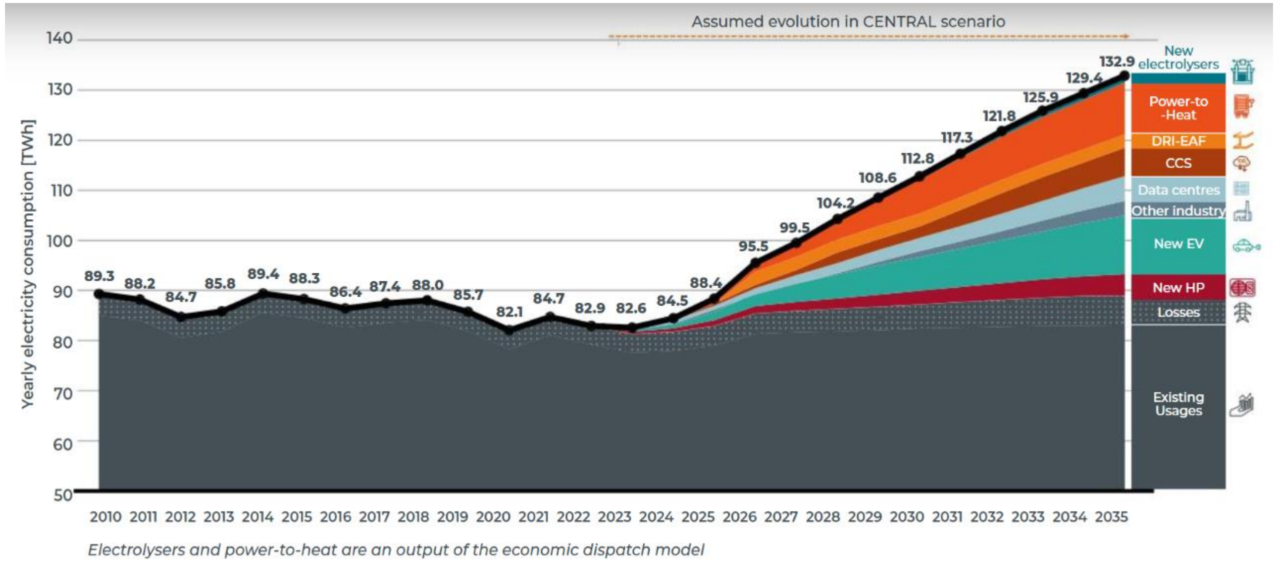
Source: NERC-FERC Winter Storm Elliott Report: Inquiry into Bulk-Power System Operations During December 2022 (link)

Why is RA important for a highly decarbonized system?



From EPRI LCRI Net-Zero 2050: U.S. Economy-Wide Deep Decarbonization Scenario Analysis [(link)]

Example from Belgium:



Source: [Adequacy studies (elia.be)]

Increased shares of variable renewables

- Energy storage, demand flexibility and thermal plant needed to balance periods of low wind/solar
- Transmission, T&D interaction and other energy system interactions will all impact needs

Increased reliance on electricity

- Often best way to decarbonize society’s energy needs
- Increases in demand coming unseen in decades
- Energy growth in developing world needs to be clean

Ongoing evolution of methods….

Cloudy with a Chance of Blackouts or Full of Hot Air?

Evaluating Weather Events in Long-term Power System Planning and Resource Adequacy Analysis

G-PST/ESIG Webinar Series | June 21, 2023

TELOS ENERGY

Resource Adequacy for a Decarbonized Future

ESIG Webinar

EPRI Transmission Operations and Planning

April 26, 2023

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Ensuring Energy Adequacy with Energy-Constrained Resources

December 2020

White Paper

BERKELEY LAB

Electricity Markets & Policy

Energy Analysis & Environmental Impacts Division

Lawrence Berkeley National Laboratory

A Guide for Improved Resource Adequacy Assessments in Evolving Power Systems

Institutional and technical dimensions

Juan Pablo Carvallo, Nan Zhang[1], Benjamin D. Leibowicz[1], Thomas Carr[2], Sunhee Baik, and Peter H. Larsen

[1]University of Texas, Austin

[2]Western Interstate Energy Board (WIEB)

June 2023

MISO'S RESPONSE TO THE RELIABILITY IMPERATIVE

- UPDATED FEBRUARY 2024 -

Living Document

This is a "living" report that is updated periodically as conditions evolve, and as MISO, stakeholders and states continue to assess and respond to the Reliability Imperative.

MISO

misoenergy.org

Ensuring Efficient Reliability

NEW DESIGN PRINCIPLES FOR CAPACITY ACCREDITATION

A Report of the Energy Systems Integration Group's Redefining Resource Adequacy Task Force

February 2023

ESIG ENERGY SYSTEMS INTEGRATION GROUP

OCTOBER 18, 2023 | EPRI RA FORUM

ISO new england

Modeling Enhancements to Support Resource Capacity Accreditation

EPRI RA Forum

Fei Zeng

TECHNICAL MANAGER | PLANNING SERVICES

And Lots More…..

EPRI

EPRI RA Initiative

Resource Adequacy Initiative

Previously shared with ESIG/G-PST in April 2023 (link)

Scope and Deliverables

RA Process

- Recommended Metrics and Criteria
- Future Scenario Database and Tool

Models and Data

- Emerging Resource & Demand Side Models
- Model Data Development Tools

Analysis Tools

- Existing RA Tool Capabilities
- New Algorithms and open-source code

Case Studies — Evaluation of existing and development of new capabilities based on 4-6 regional RA case studies covering differing RA issues and tools.

Tech Transfer — Reports and workshops to be conducted to disseminate results and to promote broad adoption in commercial tools.

25+ Participants

Southern California Edison, CPS Energy, Duke Energy, AECI (Associated Electric Cooperative Inc.), Hawaiian Electric, American Electric Power, LCRA, conEdison, Ameren, TVA, Austin Energy, NY Power Authority, LADWP (Los Angeles Department of Water & Power), Arkansas Electric Cooperative Corporation, Southern Company, SRP, NERC, MISO, SPP (Southwest Power Pool), aps, ISO new england, pjm, Entergy, evergy, New York ISO, Manitoba Hydro, NPCC

Partners

TELOS ENERGY, ASTRAPÉ CONSULTING, GE, MOMENT ENERGY INSIGHTS, Blue Marble Analytics, ENELYTIX powered by PSO

External Advisory

NARUC, NREL, ESIG, GridPath, RROs, DOE, ISOs/RTOs, G-PST, Consultants, Universities, etc.)

Foundational Case Studies

Six case studies of future systems were carried out for different levels of renewables and storage to assess a range of key questions and study tool capabilities that are relevant for each region. These do not replace standard planning studies, but are a look at how resource adequacy issues may evolve across the continent.

	Western US	Texas	SPP	MISO	Northeast	Southeast
Metrics	●	●	●	●	●	●
WDO Modeling	○	●	○	●	●	○
Climate Impacts	○	○	○	○	●	○
Load Evolution	○	●	●	○	●	○
Storage	●	●	●	○	○	○
Transmission	○	○	○	●	●	○
Download from epri.com						

EPRI Resource Adequacy Decision Support Framework

The case studies, together with extensive review of other studies and consultation with industry stakeholders, provided the evidence base upon which a guideline and decision support framework was developed.

Strategic Guidance: Assessment Design Principles

Covered in Other Webcasts

Resource Adequacy Philosophy

Use this to:
- → Review the purpose and scope of resource adequacy assessments
- → Leverage foundational principles in process design
- → Compare existing assessment processes to verify completeness

Scenario Selection Guidance

Q1 ‘24

Use this to:
- → Identify the range of variables and factors that may influence the outcome of adequacy assessments
- → Prioritize approach to considering each of the variables within assessment processes

Metrics & Criteria Guidance

Use this to:
- → Review the metrics and criteria used to measure adequacy around the world
- → Understand how metrics are calculated and the differences in the risk conveyed by the metrics

Tactical Decision Support: Study Execution Decision Support

Focus Today

Technology & System Models

Use this to:
- → Review methods by which supply and demand technologies are represented in adequacy models
- → Determine appropriate level of detail that is recommended for each asset type

Data Requirements

Use this to:
- → Review recommended data sources, variables, extent and quality required to parameterize models
- → Determine appropriate level of detail that is recommended for each variable

Assessment Tool Capabilities

Q1 ‘24

Use this to:
- → Review the analysis capabilities of commonly applied resource adequacy assessment tools
- → Compare the approaches applied within each, in the context of the recommended model and data guidance

Research Gaps

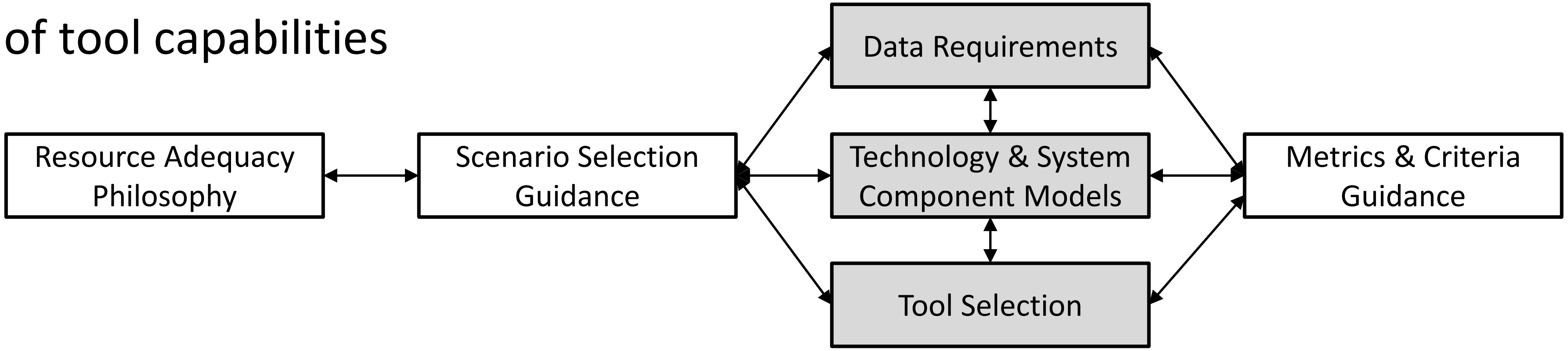
Resource Adequacy Gap Assessment

Use this to:
- → Understand the unmet challenges faced by resource adequacy stakeholders, with prioritization of next tasks.

Key Insights – Modeling

Resource Adequacy Guidelines

- Individual deliverables meant to be **used in conjunction with one another**:
  - Reference of model options by technology type
  - Data guidelines
  - Survey of tool capabilities



- Across all reports, outline "**level I – level II – level III**" functionalities for each subcategory, as well as **key outstanding gaps**

Modeling	Level I	Level II	Level III
Data, Model or Tool Characteristic	Most basic model: may be sufficient when reliance on technology addressed is low	Mid-fidelity models: may employ advanced modeling techniques for certain aspects of a technology and basic ones for others	Highest fidelity models: these models will systematically capture technology behavior with the highest level of accuracy compared to Levels I and II

Examples: Modeling options by level of fidelity

THERMAL GENERATION

	Level I	Level II	Level III
Capacity limits	Maximum generating or contractually declared capacity.	Seasonally adjusted capacity rating or declared capacity for dispatch.	Condition-based capacity rating.
Maintenance modeling	Heuristic maintenance schedules.	Optimized maintenance schedules for long-term assessments. Forecasted maintenance schedules for short or near-term assessments.	Optimized (long-term) or forecasted (short or near-term) maintenance schedules with provisions for delays and recall.
Forced outage modeling	Monte Carlo Markov Chain hourly simulation with seasonally adjusted forced outage rates.	Monte Carlo Markov Chain hourly simulation model with daily condition-based failure rates.	Monte Carlo Markov Chain hourly simulation model incorporating weather dependent/condition-based failure rates by interval.
Failure to start	Not included.	Start failure.	Condition-based start failure.
Energy limits	No model.	Fuel Pool.	Hourly fuel offtake limit and fuel pool.
Flexibility constraints	None.	Minimum generation, minimum up/ down time.	Advanced constraints plus start up, ramp rate.

TRANSMISSION NETWORKS

	Level I	Level II	Level III
Network model	Copper sheet.	Zonal.	Flow based zonal or nodal, if relevant.
Network outages	Not applicable.	May model network outages.	Models network outages.
Transmission line limits	Not applicable.	Models fixed transmission line limits. May recognize joint import limits.	Models time-varying transmission line limits and joint import limits.

Storage Modeling

All six case studies investigated multiple future capacity buildouts with varying levels of renewables and storage to assess the impact of the changing resource mix on system adequacy. Additionally, several case studies ran additional sensitivities to better understand the impact of storage modeling practices on results.

SPP case study

- Evaluated the impact of varying look-ahead periods on adequacy results.

Texas case study

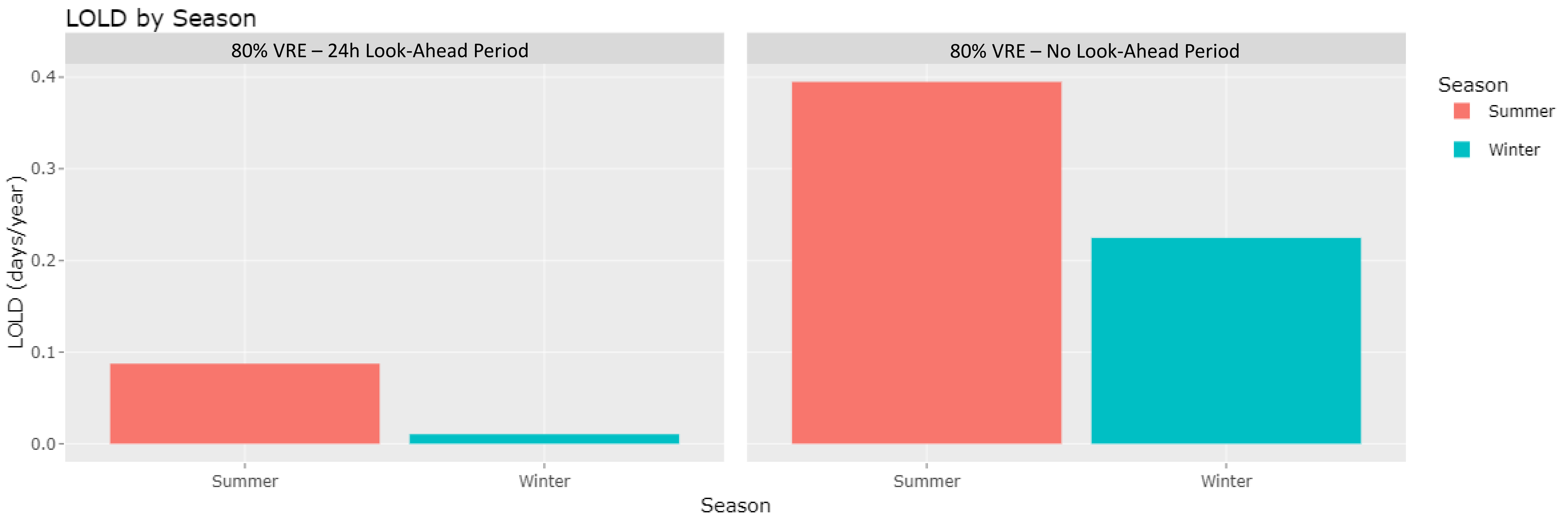
- Evaluated the impact of storage scheduling options on adequacy results (for example, minimizing system cost versus minimizing adequacy shortfalls)
- Evaluated the impact of increasing storage duration on system adequacy.
- Tracked the variation in shortfall event causes as renewable and storage penetration increased (capacity limit vs. energy duration limit vs. energy charge limit)

Western US case study

- Evaluated the impact of short-duration vs. medium-duration vs. long-duration storage on system adequacy.
- Evaluated the impact of the following parameters on medium-duration storage modeling:
  - Periodic vs. linked simulations
  - Outage derates vs. stochastic outage replications
- Develop an iterative methodology for long-duration storage portfolio to ensure that the system doesn't discharge more than it charges during a given year.
- Evaluated the impact of the following parameters on long-duration storage modeling:
  - Start date
  - Optimization window
  - State-of-charge depletion penalty

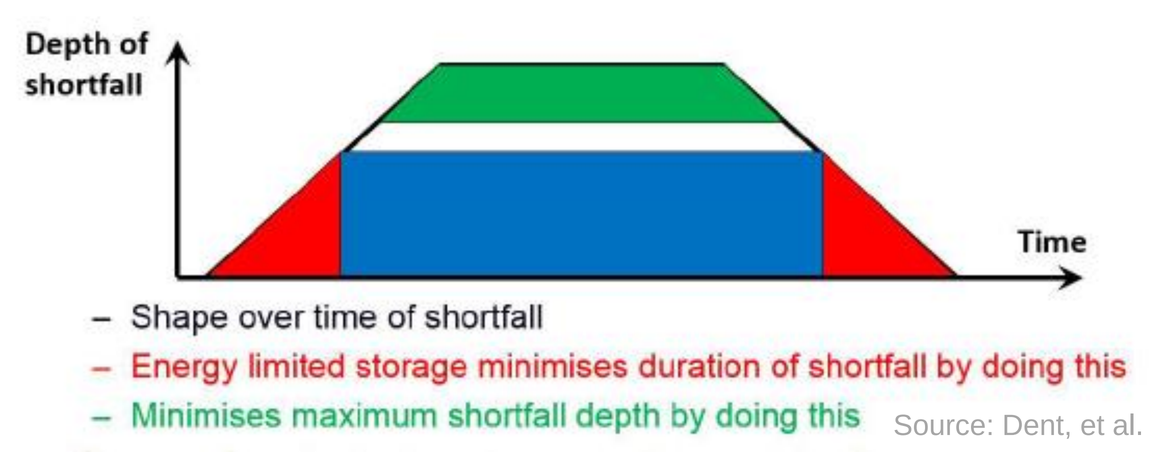
SPP case study – Impact of look-ahead

Scenario	LOLH (hours/year)	LOLD or LOLE (days/year)	LOLP (%/year)	LOLEv (events/year)	EUE (MWh/year)	NEUE (ppm/year)
80%_VRE (24h look-ahead)	0.15	0.098	0.03	0.11	98	0.33
80%_VRE (no look-ahead)	2.05	0.619	0.17	0.74	1010	3.40



With less foresight, heightened risks are expected both in summer and in winter

Texas case study – Impact of storage scheduling options



Multiple objective functions considered in PLEXOS:

- **Economic:** minimize system cost (number of hours), (PLEXOS default – minimize cost, with high unserved energy cost)
- **Min LOLEv:** minimize the number of events
- **First Come First Serve:** immediately discharge at max output as soon as unserved energy starts and do not hold energy for later periods (likely reflects actual operations, absent market intervention)
- **Min Shortfall:** minimize the depth of the shortfalls (max load unserved for any given hour, potential market operator intervention)

	Econ	Min LOLEv	First Serve	Min Shortfall
LOLE (days/yr)	0.103	0.103	0.082	0.105
LOLH (hours/yr)	0.387	0.438	0.230	0.557
EUE (MWh/yr)	724.52	724.52	724.52	724.52
Avg Depth (GW)	2.2	2.0	3.9	1.4
Max Depth (GW)	6.3	6.3	9.0	4.3
Avg Duration (hrs)	2.8	3.3	2.8	5.8

Note: Min LOLEv optimization did not result in lower LOLE than alternative methods due to step size and optimization horizon, and different definitions of event classification (i.e. consecutive hours vs. days, etc.)

Different methods of dispatching batteries under scarcity conditions yield different results for LOLE but identical results for EUE

In an energy-constrained system, an energy metric (EUE) may be best suited for a new reliability criterion

Western US case study – Long-duration storage modeling

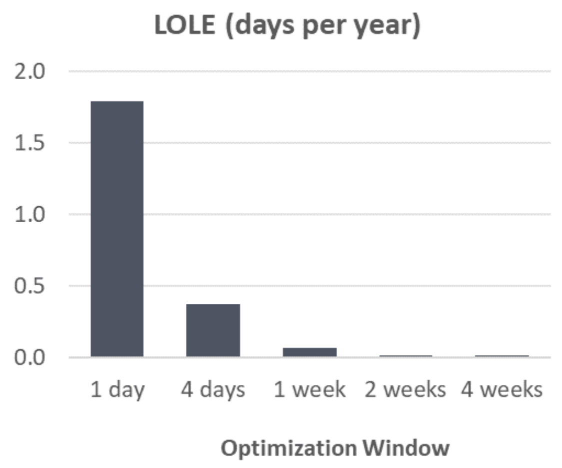
	Wind + Solar	Battery Storage	Generic Thermal	Multiday Storage
Portfolio 6	240 GW	60 GW (8 hrs)	0 GW	**43.2 GW (569 hrs)**

Default settings:

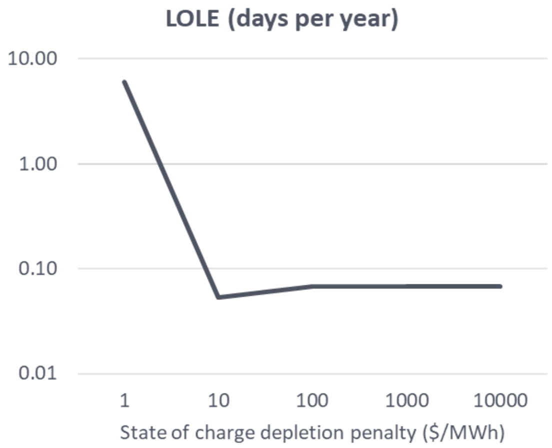
- Optimization window: 1 week
- State of charge depletion penalty: $100/MWh
- Simulation start date: Week 23 (June 4th)

- Longer optimization windows (i.e., more foresight) reduces RA risk across all metrics.
- For 1-week optimization window, state of charge depletion penalty in the last time step had to be at least $10/MWh to encourage the storage to adequately charge for future weeks.
- Beginning the simulation in June yields lower RA risk, aligns with more realistic operating practices, and reduced runtimes.

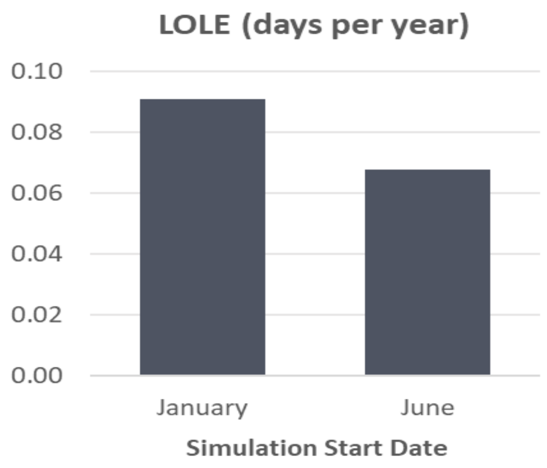
Optimization Window Tests



State of Charge Depletion Penalty Tests



Simulation Start Date Tests



How sensitive is the system to hydro and weather years?

Portfolio 4 (high VRE and storage)

EUE (MWh/year)

Weather year

Hydro year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2001	3515													980
2002	2358													224
2003	1404													29
2004	1179													43
2005	1123													7
2006	890													9
2007	2193													47
2008	1811													35
2009	3215													809
2010	1917													58
2011														
2012	32													3
2013	2632													106
2014	3750										5			1034
2015	5614			44							58			3342
2016	3374										2			1119
2017	1029													15
2018	2131													129
2019	1318													2
2020	1716													21

RA risk shifts to 2007 as the system incorporates more renewables and storage, potentially due to the August 2007 heat wave, which saw more cloud cover than the August 2020 event.

Portfolio 6 (high VRE, multi-day storage)

EUE (MWh/year)

Weather year

Hydro year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2001								5606			3.E+04			
2002														
2003	5.E+04													
2004														
2005														
2006														
2007											632			
2008											539			
2009											455			
2010														
2011														
2012														
2013											1053			
2014	1.E+05										2026			
2015								1.E+04			3.E+04			
2016											223			
2017														
2018														
2019														
2020											512			

Challenging years are less frequent, but events are much larger. Weather risk arises in 2017, which saw both a cold winter and a hot summer in the West
RA risk is much more dependent on the combination of weather and hydro conditions because the system is energy-limited.

WECC case study results

Correlated Outage Modeling

Varying approaches to weather-dependent outage modeling were identified and applied across all case studies, depending on data availability, tool capability, and modeling choices.

Models

Many modeling choices:

- Model weather-dependent unavailability as a capacity derate vs. as a forced outage rate
- Recalibrate base forced outage rates vs. not
- Model the impact of natural gas unavailability and/or the impact of extreme temperatures on generating equipment
- Adjust time-to-outage values only or both time-to-outage and time-to-repair values
- Adjust full outage rates only or both full outage rates and partial outage rates

Data

Limited data availability:

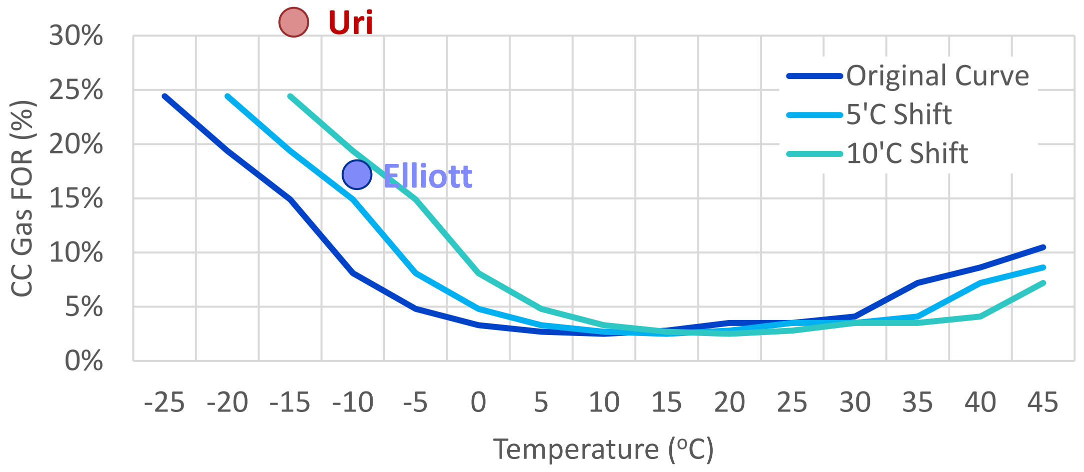
- Create custom capacity derate information using historical GADS and temperature data
- Use data from CMU method (Murphy et al)
    - Either use as is, or shift based on location compared to PJM
- Assume all affected units are derated or offline past a certain temperature threshold
    - Affected units– consider plant vintage? Consider dual-fuel units?
    - Temperature threshold – What temperature threshold to use? Daily or hourly? Averaged over what region?

Tools

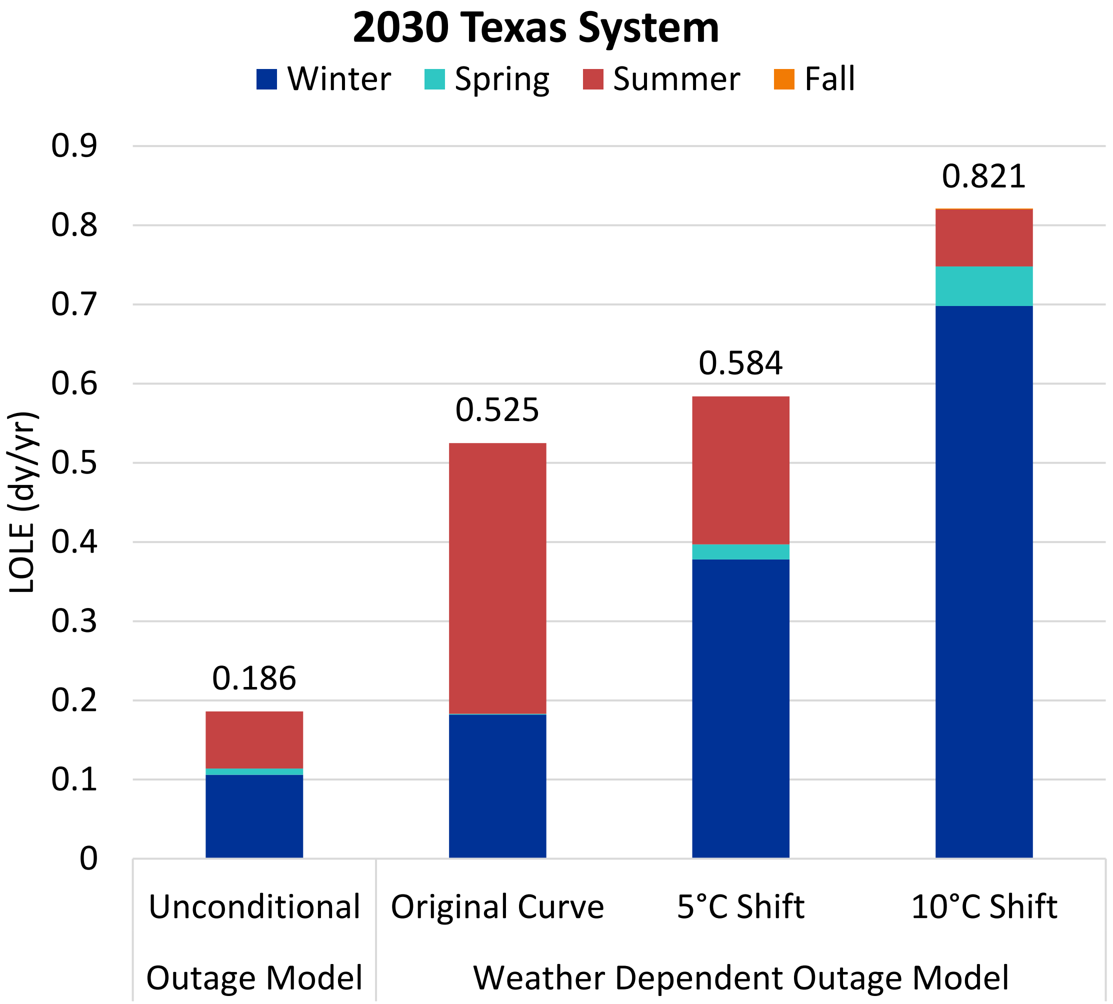
Varying tool capabilities:

- Some tools allow for forced outage rates to be varied directly as a function of temperature.
- Some tools allow for forced outage rates to be varied temporally, but not as a function of temperature. Hourly forced outage rates can be created which reflect the temperature variation, but they will vary from one weather year to another, and results must be merged in post-processing.
- Some tools don't allow for forced outage rates to be varied hourly or as a function of temperature, and workarounds must be used.

Texas case study - Weather Dependent Outages Increase LOLE Significantly



- Introducing WDO causes a significant increase in observed loss of load events, even when the *average* outage rate is the same
- This risk is not captured in many of today's resource adequacy analyses
  - Using unconditional, average outages rates dampens variability and may understate risk
  - Generation is highly susceptible to timing of increased outage risk, as observed with changing seasonality due to shifting the outage rate function 5° and 10°C
- However, this analysis does not consider:
  - Impacts of weatherization measures
  - Explicit natural gas pipeline and electric power sector coupling



NOTE: The "Unconditional Outage Model" uses a higher annual outage rate such that the *average* outage rate between the unconditional outage model and the weather dependent outage models are consistent. than the Base Case of the ERCOT Case Study

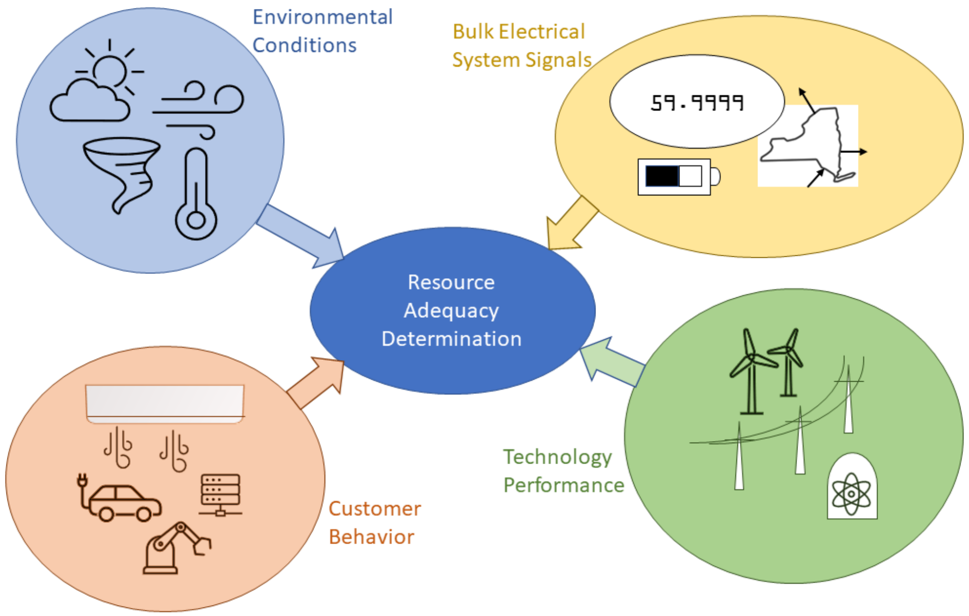
Data Deliverable – Topics Covered and Aims

Weather Data
- Temperature
- Precipitation
- Wind
- Climate Change
- Solar Radiation

Supply Resource Data
- Thermal Generation
- Battery Storage and Hybrid Power Plants
- Solar Generation
- Hydroelectric Power and Pumped Storage
- Wind Generation
- Hydrogen

Customer Demand Data
- Historical Load Data
- Distributed Generation and Storage
- Additional Data Needs for Demand Modeling

Energy System Data
- Transmission and Distribution
- Gas/Hydrogen
- Outage Data



Reference document for the current state of tool functionality across several resource adequacy assessment tools.

Guide tool users towards the most appropriate tool for the study at hand, and **help tool developers better understand how their tool's functionality compares to others in the industry**.

Data Guidelines: Examples of Summary Tables

GENERATION	Level I	Level II	Level III
DER facilities, generation data	Aggregate capacity of DER generation and storage facilities, sufficient to allow estimated generation and charge and discharge	Comprehensive facility location and technology data for generation and storage facilities, together with sampled data, allowing for more accurate estimation of generation, charge and discharge.	Telemetered generation, charge and discharge data for all DER facilities, whether at individual facility or nodal aggregation.
Wind Power	Five years of hourly data; speed to power transformation based on generic power curves; geographic diversity of generation captured at coarse resolution	Decades of hourly data (40+ years), validated speed-to-power conversion, benchmarked against real-world generation data representing current and near-future wind technologies	Level II with climate trends included; uncertainty modeled; new/future wind technology represented
Solar Power	Five years of hourly GHI data at 0.25-degree resolution, conversion to power based on generic power curves.	Decades of 5-minute data from in-situ instrumental observations of GHI/DNI, used to generate simulated hourly mean and generation time series as well as hourly statistics of 5-minute variability, conversion to power including tracking and inverter modeling.	Decades of 5-minute GHI/DNI from a combination of modeled and observed radiation, converted to generation using power curves and tracking algorithms particular to the modeled facility.

Transmission & Outage Data	Level I	Level II	Level III
Transmission Capacity and Transfer Data	None: transmission neglected in copper-plate model for resource adequacy, with fixed prescribed imports and exports to neighboring grids.	Transmission limits prescribed for zone-to-zone and grid-to-grid transmission, but variations within limits set according to modeled excess capacity in each zone.	Detailed model of transmission line ratings with weather inputs, nodal model of transmission within grid and between grid and neighboring grids.
Thermal Power (Gas, Gas+CCS, Biofuel, BECCS, Hydrogen) – Extreme	Extreme outages from 15+ years of forced outage historical data	Weather-dependent outages (WDO) generated using 30+ years of historical forced outage and temperature data	WDO and common cause outages generated using 50+ years of historical forced outage and temperature, coupled with predictive modeling of extreme weather events

Survey of Software Tools

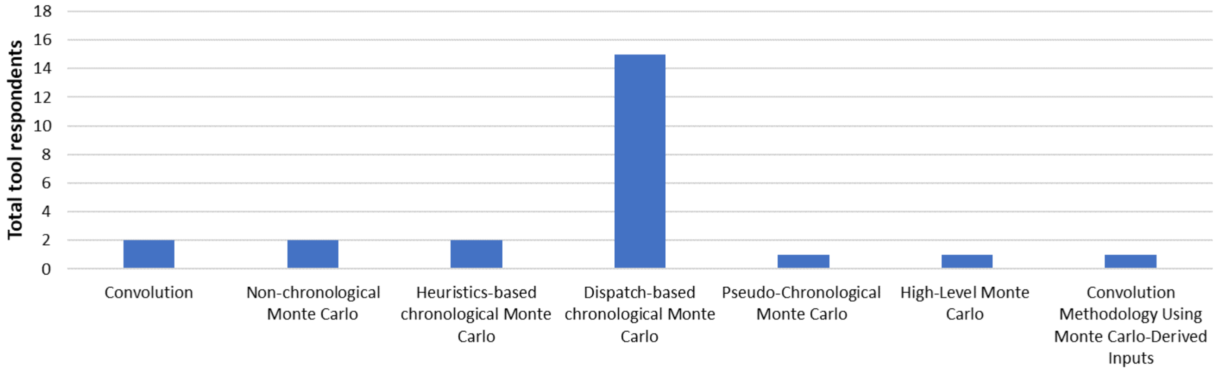
Deliverable Expected to be Published in March 2024

Tool Components Covered and Tools Surveyed

Core Functionality	Demand-Side and Storage Resources	Networks
Analysis Approaches	Energy Storage	Transmission Network
Risk Metrics	Hydropower	
Generator Outages	Demand Flexibility	
Weather Uncertainty		

Tools Surveyed for the project:

Tool Category	Tool Name	Tool Provider
Commercial	2-4-C	Ernst & Young (EY)
	Aurora	Energy Exemplar
	BID3	AFRY
	Crystal Super Grid	Artelys
	Enelytix	Polaris Systems Optimization and Newton Energy Group
	GridView	Hitachi Energy
	MARS	General Electric
	Plexos	Energy Exemplar
	PowerSIMM	Ascend Analytics
	PROMOD	Hitachi Energy
	SDDP	PSR
	SERVM	Astrape
Open source	Antares	RTE International
	GridPath	Blue Marble Analytics
	PRAS	National Renewable Energy Laboratory (NREL)
Custom	MAVRIC	Western Electricity Coordinating Council (WECC)
	RECAP	Energy + Environmental Economics (E3)
	GRARE	Centro Elettrotecnico Sperimentale Italiano (CESI)



Outage Modeling

Core functionality

Forced outage modeling method

Least accurate ← Capacity derate — Convergent outages — Outage probability rate — Discrete outage failure durations — Markov modeling — MTTF/MTTR (all distributions) → **Most accurate**

Best practice for extreme weather modeling:
A robust forced outage modeling method
+ sufficient add-on functionalities for accurate system representation during times of stress

Add-on functionalities

Partial derates
→ Traditionally only considered for thermal units, but should be considered for wind, solar, and energy storage units – where partial derates are more common that full plant-level outages.

Start-up modeling
→ During extreme events, many units may start up in close succession to meet a system need, and some of these units may be switching to a different fuel, or rarely called upon, and thus are at an increased risk of start-up failure.

Varying outage statistic parameters
→ **Time-based**: Vary failure rates for each study operating period (pre-processing required)
→ **Condition-based**: Directly link forced outage rates to key model variables (such as temperature)

Contingency outages
→ Useful when modeling natural gas shortage effects: derate or outage all units sharing a natural gas pipeline or a certain type of fuel contract during a cold weather event.

Chronological approach

- Main modeling methodologies:
  - Markov-based (exponential distribution)
  - Using other distributions
- Alternative approaches:
  - Convergent outages
  - Discrete outage failure durations

Non-chronological approach

- Main modeling methodology:
  - Outage rate probability
- Alternative approach:
  - Capacity derate

Not explicitly modeled

- Workaround possible if generator capacity can be modified on an hourly basis

Key Insights – Emerging Resource Modeling

Demand Side Resources:

Demand response constraints
- Power
- Energy
- Duration
- Number of dispatches

Other considerations:
- Linking demand response to other variables:
  - Temperature
  - Load level
- Representation of uncertainty in customer response
- Representation of gradual decrease in load responsiveness

Temporal variation across constraints:

More flexible

- Defined for every timestep of the simulation
- Defined for every day of the week or hour of day
- Defined for every month
- Defined by season

Less flexible

Energy Reservoir Modeling (Storage):

Dispatch objectives:
- Economics (most used in optimization-based Monte Carlo solvers)
  - Dispatch to minimize total system cost or maximize unit profit
- Reliability (most used in heuristics-based Monte Carlo solvers)
  - restricting all storage discharge to hours which would otherwise experience loss of load
- Peak shaving
  - Look for tools which can apply this to net load

Some tools can use a multi-purpose dispatch objective!

Only required for optimization-based Monte Carlo solvers:
- Optimization window
  - A tool with a flexible user-defined optimization window length is important
- Penalty on storage state-of-charge depletion

Energy Reservoir Model
- Energy capacity
- Power capacity
- Roundtrip efficiency

Efficiency:
- Roundtrip charging/discharging efficiency
- 'Self-discharge'/'carry-over' efficiency
  - Only necessary if storage assets are expected to be dispatched infrequently

State-of-charge:
- Continuously monitored
- Only monitored during at risk periods
  - Not appropriate for "energy charging" adequacy events (where storage may not have time between events to fully recharge)

Outage modeling:
- Not explicitly modeled
- Modeled using a capacity derate approach (deterministic)
- Modeled using a probabilistic outage modeling approach

Additional constraints:
- Charging restrictions (for example, only charging when surplus renewable generation is available)
- Discharging restrictions (for example, ensuring some energy is kept available for ancillary service provision)

Considerations for Tool Selection

Other Factors to Consider Beyond Tool Specifications:

Tool selection factors	Example use cases		
	Research project	Yearly update project	Quick turnaround screening study
Availability of detailed models	++	+++	+
Cost	+++	++	+
Computational speed	+	++	+++
User interface	+	++	+++
Software support	+	+++	++
User manual	+++	++	+
Access to nonproprietary databases	++	+	+++

\+ Low importance   ++ Medium importance   +++ High importance

Technical Study Considerations for Tool Selection:

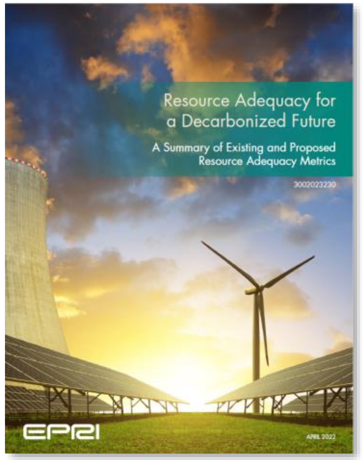
If modeling a system…	Then prioritize…
… with a large amount of energy limited resources	➔ dispatch-based chronological Monte Carlo sampling method (Section 3) ➔ robust storage, hydropower and/or demand response modeling (Sections 8, 9, and 10)
… at risk of extreme weather events	➔ report percentile-based metrics (Section 4) ➔ correlated timeseries data (weather-based resources, load, temperature, etc.) (Section 6) ➔ conditions-based forced outage modeling (Section 5) ➔ start-up failure modeling (Section 5) ➔ contingency outages to represent widespread outages due to fuel shortages (Section 5)
… in the operational planning timeframe	➔ chronological Monte Carlo sampling method (Section 3) ➔ multi-stage economic optimization (Section 3) ➔ no forced outage foresight (Sections 3 and 5) ➔ short-term weather forecast error (Section 6)
… at risk of shoulder season shortfall events	➔ a robust maintenance outage modeling methodology (Section 5)

What comes next?

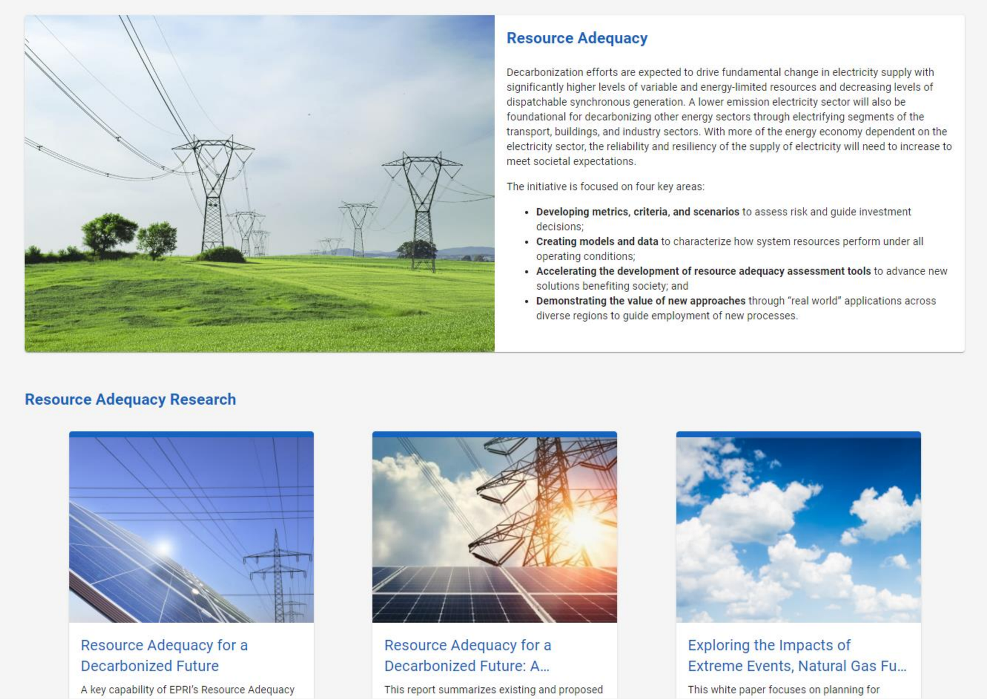
EPRI initiative – Where can I find additional information?

Available today:

- Website is already live, with initial set of reference reports and all case study reports already linked.
- Will be adding material to this as it gets published.
- In-depth technical reports (2-3 still to come!)
  - Metrics and criteria recommendations
  - Survey of tool capabilities
  - Scenario generation guidelines
- Summary papers and videos



www.epri.com/resource-adequacy



Gap Severity Rankings

LOW

- [5] Incorporating consistent and correlated weather datasets

MODERATE

- [6] Need for improved and more detailed resource adequacy metrics
- [6] Interregional coordination
- [7] Holistic integration of resource adequacy with other planning activities
- [7] Improved load forecasting… weather impacts, electrification, and climate

SEVERE

- [9] Identification and analysis of outlier, high-impact, low-probability, events
- [9] Winter risk associated with fuel supply and weather dependent outages

Reflects need for further awareness, R&D and integration into RA studies

Resource Adequacy – Current Key Issues We Have a Good Handle On

https://gridops.epri.com/Adequacy

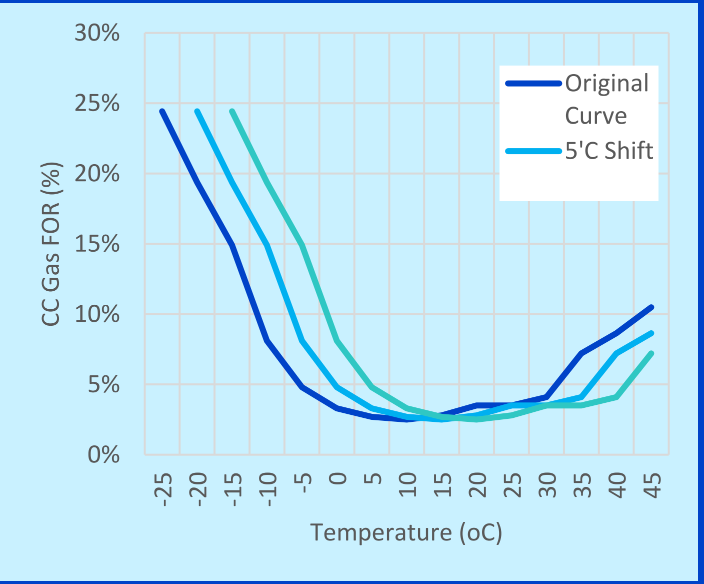
SCAN ME

- **Additional metrics/ criteria needed to assess adequacy risk**

Region	Daily LOLE	Hourly LOLE	EUE-norm.
A	0.10	0.15	0.37
B	0.10	0.34	0.99
C	0.10	0.39	3.37
D	0.10	0.25	1.00
E	0.10	0.48	2.54
F	0.10	0.28	0.34
Metric Scope	Frequency	+ Duration	+ Magnitude
Relative Risk	**Same**	**3X**	**10X**

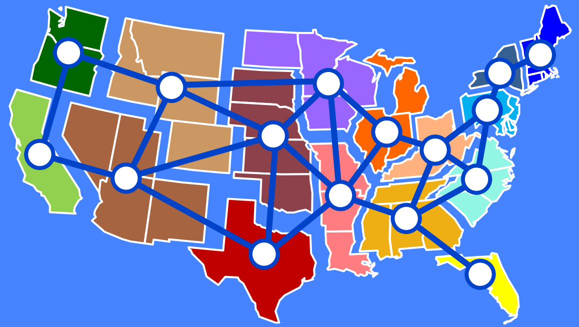
Multiple metrics may be needed; more work to set criteria

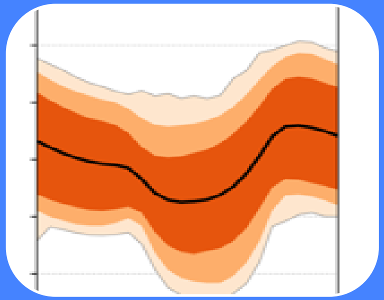
- **Need to consider range of operational conditions and resource behavior**



Weather dependent outages, look across seasons, etc.

- **Need more comprehensive data and models**

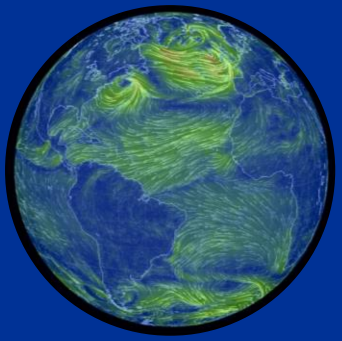




Long, coherent datasets are needed to describe load/resource behavior

What are things we know less about?

- **How do we consider extreme events and climate change?**



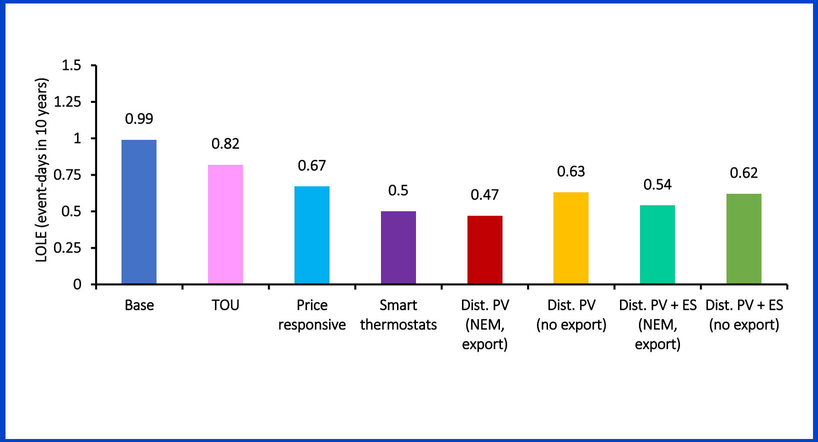
Cold Snap

Severe Storm

Heatwave

Improved datasets and incorporation into RA assessments

- **How do we include changes in load – demand flexibility, electrification, ?**



Load forecasting, large and small demand side resources

- **How do we better assess reliability contribution of resources?**

Improved capacity accreditation methods and tools to support

EPRI Resource Adequacy Forum

What is it?

Deep dive series on RA modelling from leading projects and assessments

Who is it for?

Practitioner deep dive on topical study followed by reactions and topical break-out

Format

Practitioner deep dive on topical study followed by reactions and topical break-out

21
February
Webcast 4: Extreme Events

17
April
Webcast 5: Energy Storage

19
June
Webcast 6: Wide-Area Assessments

RA Knowledge Center – In-Progress

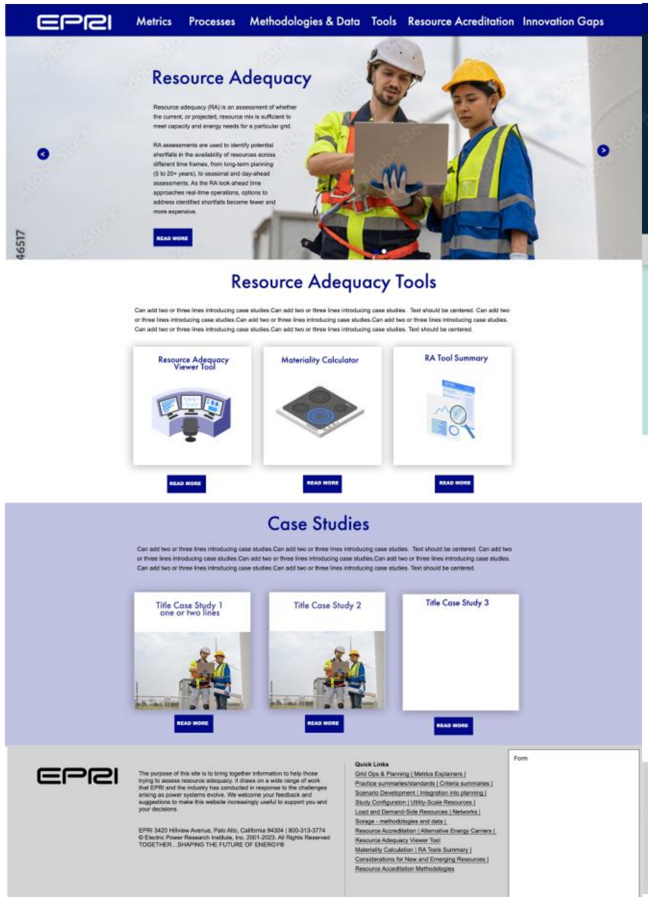
Goal

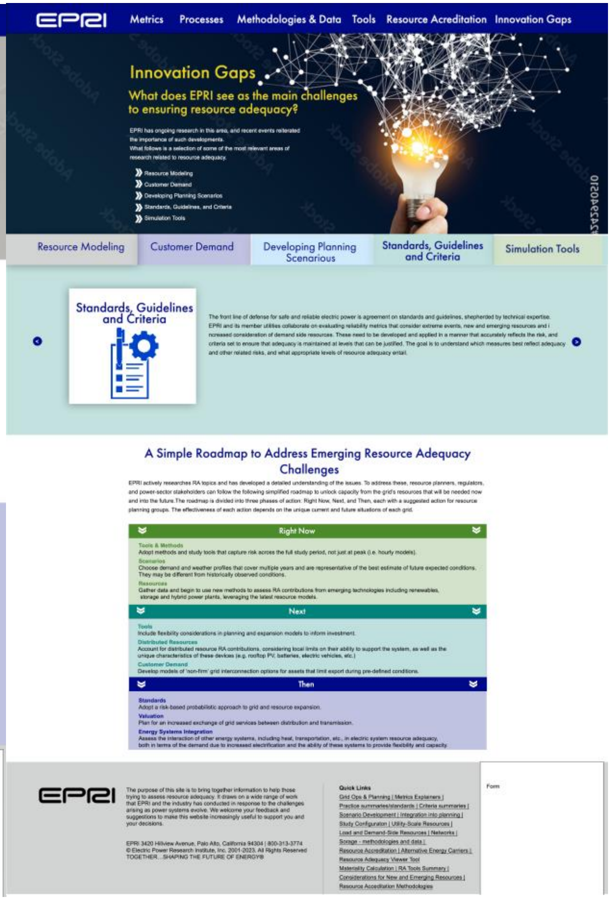
To provide clear, complete and insightful information to support practitioners in their selection of methods to assess resource adequacy.

Mailing List – Scan Below or [Click Here]

https://gridops.epri.com/Adequacy

SCAN ME





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